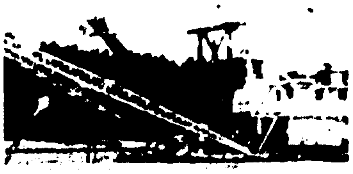
US Army Corps of Engineers



DREDGING OPERATIONS TECHNICAL SUPPORT PROGRAM

TECHNICAL REPORT D-92-1

SEASONAL RESTRICTIONS ON DREDGING: AN APPROACH TOWARD ISSUE RESOLUTION

by

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January 1992

Final Report

Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	January 1992	Final report

4. TITLE AND SUBTITLE

Seasonal Restrictions on Dredging: An Approach Toward Issue Resolution

5. FUNDING NUMBERS

6. AUTHOR(S)

Mark W. LaSalle

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

US Army Engineer Waterways Experiment Station
Environmental Laboratory
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

US Army Corps of Engineers, Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

Technical Report D-92-1

11. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report describes the use of technical review committees to address problem environmental issues. This approach requires that (a) all parties involved realize that coordination and cooperation are essential in reaching some sort of resolution, and (b) conclusions or recommendations developed through this process must be based on sound technical information. The approach is illustrated through descriptions of two technical resolution committees that were formed to address issues concerning seasonal restrictions on dredging in estuarine ecosystems. Each committee produced a set of conclusions and recommendations and also provided an extensive review of pertinent information on various aspects of the issues that were addressed. Results of both exercises were published in peer-reviewed form, which greatly enhanced their acceptability by the scientific community at large.

14. SUBJECT TERMS

Dredging — Seasonal restrictions
Issue resolution

15. NUMBER OF PAGES

26

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

Contents

Preface

This report was prepared by the Environmental Laboratory (EL) of the US Army Engineer Waterways Experimental Station (WES), Vicksburg, MS, under the direction of the Dredging Operations Technical Support (DOTS) Program of the Environmental Effects of Dredging Programs (EEDP). Dr. Robert M. Engler is the EEDP Program Manager. Mr. Thomas R. Patin is the DOTS Program Manager. Mr. Joseph Wilson is the DOTS Technical Monitor.

This report was prepared by Dr. Mark W. LaSalle of the Coastal Ecology Group (CEG), Environmental Resources Division (ERD), EL, under the general supervision of Mr. Edward J. Pullen, Chief, CEG, Dr. Conrad J. Kirby, Chief, ERD, and Dr. John Harrison, Chief, EL. Technical critiques were provided by Drs. Douglas G. Clarke and Gary Ray, EL, and Messrs. Edward J. Pullen and Dave A. Nelson, EL. The report was edited by Mrs. Janean C. Shirley of the WES Information Technology Laboratory.

Commander and Director of WES was COL Larry B. Fulton, EN. Technical Director was Dr. Robert W. Whalin.

This report should be cited as follows:

> LaSalle, M. W. 1992. Seasonal restrictions on dredging: An approach toward issue resolution. Technical Report D-92-1. Vicksburg, MS: US Army Engineer Waterways Experiment Station.

1 Introduction

Background

In an effort to avoid or minimize potentially detrimental effects of dredging activities on biological resources, State and Federal resource management agencies often recommend that dredging be limited to periods of minimal biological activity (LaSalle et al., in preparation). These seasonal restrictions are based upon suppositions about the effects of dredging-induced environmental alterations on a given resource. Ideally, these restrictions should be based on sound technical information about the relationships between alterations and their effects on organisms (LaSalle et al., in preparation). In reality, however, specific information regarding potential effects is lacking for many organisms. Consequently, resource agencies often justify restrictions by "playing it safe" with recommendations based on "reason to believe" criteria. In most cases, Corps Districts attempt to comply with seasonal restriction requests, particularly when these restrictions are based on sound technical information. In some cases, however, restrictions have been imposed despite the existence of technical information contradicting the basis for the restriction (LaSalle et al., in preparation). Such actions may limit a District's ability to complete a project in a cost-effective, safe manner. These actions can lead to disagreements between Corps Districts, charged with maintaining navigable waterways, and State and Federal agencies, charged with protecting biological resources.

In an effort to foster interagency coordination and cooperation in addressing District activities, some Corps Districts have formed project advisory committees, composed of representatives from resource management agencies having formal project review authority (see LaSalle et al., in preparation, for a review). These committees review all aspects of a given project in an effort to reach mutually agreeable solutions for issues generating conflict (e.g., seasonal restrictions). In the case of unresolved issues, however, the needed expertise may not be available in an advisory committee to adequately address the subject. One approach toward resolving such contentious or minimally understood issues is the establishment of technical review committees. These committees ideally serve to review all aspects of an issue outside of the political arena, which

so often overshadows positions taken by opposing sides. Committees are charged with reviewing available technical information concerning physical, chemical, or other alterations and their effects on organisms, and formulating recommendations concerning the issue in question. They can serve in either an advisory or arbitration capacity. LaSalle et al. (in preparation) briefly described two such committees and emphasized their roles in addressing the subject of seasonal restrictions.

Objective

This report provides a detailed outline of the process by which technical review committees are formed and operated. It describes a process to address any type of inquiry concerning potential impacts and draws upon the recent experiences of two committees formed to address either very specific or very broad issues related to seasonal restrictions on dredging.

2 Basis of a Technical Review Committee

Overview

The approach described here for dealing with unresolved issues is modeled after that described by Prezant (1986) and is based on two major assumptions (specifically detailed by Carriker et al. (1986)): (a) that cooperation and coordination between parties on all sides of an issue are essential to reaching a meaningful understanding, and (b) that conclusions and/or recommendations **must** be based on technically sound information. Additionally, all parties involved must be flexible in their approach to dealing with natural systems as well as in dealing with each other.

> The need for flexibility lies in the fact that annual variability in natural aquatic systems, particularly estuaries, is to a great extent unpredictable. Any flexibility extended at one time, by any party, should not be looked upon as setting a precedent for the future, but simply reflects a response to the variability in the natural system at a particular time and place. Site specificity is inevitable and must be a major consideration. (Carriker et al. 1986)

All too often, however, management decisions are not based on the recognition of inherent variability of natural systems, nor is there consideration for the system as a whole. Potential impacts to organisms and/or habitats must be placed in perspective with the system in time and space.

Steps in the Process

The steps in the proposed process (Figure 1) are much like those followed in planning and conducting any scientific inquiry. Although these steps may seem obvious, it is useful to outline them so that everyone involved understands the entire process as well as the order in which tasks should be conducted. For example, defining the objective of the

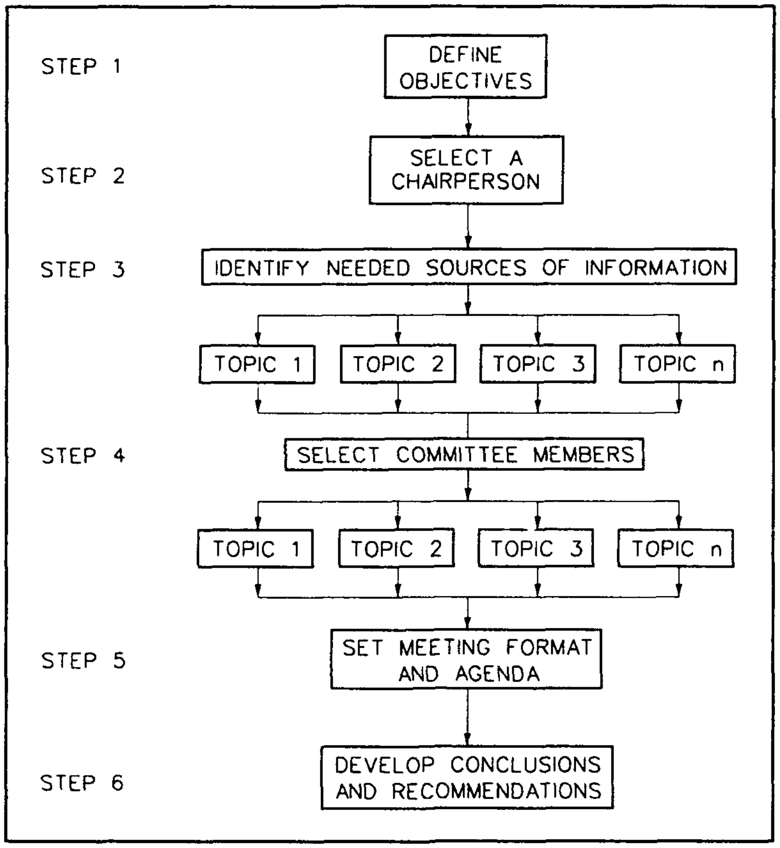

Figure 1. Flowchart of steps required in developing a technical review committee

are obvious first steps, which largely determine how appropriate sources of information as well as potential committee members are identified. The first two steps should be closely coordinated, as each will help define the other.

Defining the Objective(s)

Defining the objective(s) of the committee's effort is the most important step in the process since it not only frames the question(s), but also helps to determine the topics to be included. The objectives should also reflect a clear focus on providing input into management decisions. Care must be taken to state the objectives in clearly definable terms that can lead to some logical end point (i.e., a decision or set of recommendations). Vaguely stated objectives (e.g., determination of the impacts of dredging on biota of a given river) would require expertise on such a broad scale that the committee would become too large and cumbersome. In cases where there is a need to consider a wide range of topics, it is useful to subdivide the work among smaller groups.

Selecting a Committee Chairperson

The committee chairperson is a central figure in the process and should be selected prior to or simultaneous with defining the objectives of the work. This is a critical step, given that this person will be responsible for identifying appropriate topics and experts capable of providing needed sources of information. Several important factors should be considered when making the choice of a chairperson. It is extremely important to identify a highly competent individual to serve in this capacity, since he or she will determine the breadth and depth of coverage for any and all topics that will be considered. He should have both a strong technical background and be capable of working with people, even in confrontational situations. In addition, the chairperson will also set the tone of the proceedings and keep the group within an agenda and time frame that can lead to reaching some sort of conclusions and recommendations. It is important for this person to have leadership qualities in order to keep the process moving on track. This person should also have a reputation of impartiality in order that any conclusions or recommendations resulting from the exercise will be recognized as unbiased. Without this recognition, the entire effort will fail to meet the underlying objective of reaching some sort of resolution of the issue in question. To this end, the chairperson, if possible, should be identified outside of the major agencies having interest in the issue.

Identifying Needed Sources of Information

Sources of information needed to cover identified topics (e.g., target organisms, types of impacts, etc.) will usually be apparent, given the stated objectives of the exercise. However, it must be remembered that a major objective of any effort is to place the alteration into perspective with the ecosystem within which the activity occurs **and** with the biological (e.g., emigration, mortality, growth) responses of the organisms of concern. Consequently, peripheral topics which will help relate impacts to the entire ecosystem may not always be obvious. In addition, responses by and impacts to organisms may be indirectly rather than directly related to other associated alterations (e.g., loss of food resources through habitat disturbance). Identifying these potential topic areas requires a good understanding of the system itself and the organisms involved, as well as the literature base from which needed information can be obtained. Three broad areas of information should be included: information on the predicted magnitude and extent of each alteration, information on the natural background levels of analogous alterations (e.g., minimum, maximum, and average suspended sediment concentrations), and information on the known responses of organisms to each type of alteration (including the degree to which organisms respond to ambient levels in these parameters).

A potential limiting factor in identifying sources of information involves the fact that much of this information may not be readily available in widely accepted professional publications (i.e., peer-reviewed literature). Often pertinent information can only be found in non-reviewed "gray" literature. This presents a potentially serious problem in that knowledge of the existence of this information is often limited. Consequently, important, insightful data may go "undiscovered" and not contribute to addressing the issue. While there continues to be debate as to the "value" and "role" of this "gray" literature (Collette 1990; Wilbur 1990), it is nonetheless useful and in many cases it represents the only information on certain aspects of a given issue. More formal vehicles of dissemination (e.g., journal papers, symposium proceedings) do not encourage publication of "marginal" data (i.e., less rigorously organized results of monitoring studies) or management-related information. Wilbur (1990) discusses the dilemma of the "gray" literature and provides suggestions concerning how resource management agencies should approach publication of their information.

Committee Member Selection

This task evolves from decisions made about topic areas to be included in the exercise, as well as the chairperson's knowledge of available researchers working in these areas. The number of persons needed to adequately review a given issue will depend on the number of areas included, but should be kept to a minimum as much as possible. The speed at which the process proceeds and the probability that the topics at hand will be covered well are generally inversely related to the number of committee members involved.

As with the choice of the chairperson, care should be taken to select committee members who are as unbiased as possible toward the overall issue and are known to work well within groups of this kind. It serves no purpose to include individuals who have previously taken a position on an issue and would be reluctant to modify their position based on factual determinations. It is imperative that each member be recognized for his or her technical expertise in a given subject area. Each person will hopefully be aware of major sources of available information within their areas of expertise, including the "gray" literature.

Meeting Format and Agenda

The format of the meeting itself should be broadly divided into two major parts: the presentation of available information by committee members on their respective topic areas, followed by discussion periods during which a consensus is reached on the meaning of available information

with respect to an issue (e.g., seasonal restrictions). Initial efforts should seek to cover all of the major topic areas identified. The ensuing discussions should be devoted to placing the accepted information on alterations of concern into perspective with what is known about the responses of organisms to these alterations, including negative, positive, or neutral responses. For example, it may be agreed upon that a suspended sediment concentration of 100 mg/L may be acceptable for juvenile or adult fishes, but unacceptable for eggs or larvae.

When topics cannot be stated in narrowly defined terms, it may be useful to suodivide the inquiry among smaller groups, which tend to work more efficiently. The chairperson or subcommittee chairpersons can subsequently summarize overall discussions and conclusions of these smaller groups during a separate discussion period involving the entire committee.

Developing Conclusions and Recommendations

A final and necessary part of any debate is a period of discussion in which overall conclusions and recommendations are made by the committee as a whole. It is here that the committee chairperson must insure that all aspects of the issues are included in the debate, even if a consensus is not reached for some issues.

As previously discussed under sources of information, three broad areas of information must be considered when developing conclusions and recommendations. Consideration must be given to: (a) what is known about the magnitude (spatial and temporal dimensions) of the alteration, (b) the natural background levels of the altered parameters, and (c) the responses of organisms to both natural and elevated levels of these alterations. This information, along with data on site-specific conditions, can then be used to place dredging-induced alterations into perspective within a given environment.

Conclusions should be sought with regard to the consequences of alterations (at the levels predicted) on the organisms of concern under all recognized scenarios. In general, two types of conclusions are possible. The first includes conclusions based on sufficient information that impacts to a resource or response of an organism to a given alteration can be predicted or estimated with confidence. The second includes cases of insufficient technical information, where meaningful conclusions may not be possible. Recommendations may also fall within these two categories, and can include suggestions on the types of information that would be required before a conclusion would be possible.

Even when a conclusion (i.e., consensus) is possible, it may be contingent upon the level of a given alteration and some sort of threshold level above or below which different conclusions are drawn. For example, a threshold may be recognized at some point along the range of a given

alteration (e.g., concentration of suspended sediment) which can be used to make statements such as: if concentrations remain below X mg/L, then minimal or no impact at all would be expected. Multiple levels of alterations and inferred impact may also be predicted. The levels at which the decision thresholds are set will reflect the amount of available information on the effect of the alteration on the organisms of concern.

Regardless of the nature of the conclusions and recommendations that are made, at a minimum the work of the committee can serve as a "state-of-the-art" summary of information on the subject from which future work can be planned. It is highly recommended that the results of the committee's work, including reviews of all topic areas and summaries of conclusions and recommendations, be documented in written form. In this way, the effort will eliminate the need to reassemble this information at a later date, particularly if the information is recorded in an easily identifiable and accessible form (i.e., publication). It is further suggested that this be done through either a peer-reviewed journal or other rigorously edited forum (e.g., Sea Grant publication) in order that the results be accepted by the scientific community. This also avoids any stigma of partiality or bias.

Using these publications or forums also guarantees that the information will be widely disseminated and accessible. As noted in the following examples of past committees, the chairperson served in the capacity of editor of the subsequently published proceedings.

3 Examples of Issue Resolution Committees

Issue: Entrainment of Larval Oysters by Hydraulic Dredges

Background

In August 1985, the US Army Engineer Baltimore District, in conjunction with the US Army Engineer Waterways Experiment Station (WES), sponsored a technical workshop to discuss the topic of entrainment of oyster larvae by hydraulic cutterhead dredges (American Malacological Union 1986). This issue evolved from a special concern, voiced by the Maryland Department of Natural Resources, that the activity of hydraulic dredges "near" productive oyster bars during the spawning season represented a significant impact on the larval oyster population.

Objective

The primary objective of this workshop was to attempt to resolve this issue by bringing together authorities on oyster biology, oyster fisheries, estuarine dynamics, and dredging operations. These experts were asked to address the question: "Do hydraulic cutterhead dredges lethally entrain large numbers of larval oysters and, if so, to what extent will this reduce oyster production in Chesapeake Bay?" (Prezant 1986).

Chairperson and topic selection

Dr. Robert S. Prezant of the University of Southern Mississippi was selected by WES scientists to plan and convene the meeting based on his expertise in the area of estuarine molluscan ecology. Dr. Prezant was also the Senior Editor of the American Malacological Bulletin and agreed to edit and publish the proceedings of the workshop as a special edition of the Bulletin. Based on his oral presentation, each participant was asked to

submit a manuscript following the meeting. Manuscripts were then peer reviewed prior to publication. Topics of workshop presentations included: opposing views on whether restrictions were valid based on available knowledge, aspects of the physical and chemical alterations around an operating dredge, characteristics of water circulation in Chesapeake Bay, and various aspects of oyster biology pertinent to the topic of larval entrainment (Table 1).

Committee member selection

Appropriate technical experts in each of the above topic areas were invited to participate. Experts included representatives of the State of Maryland and the Baltimore District, who prefaced the meeting by stating the opposing positions on the issue (along with supporting arguments and data). Additional attendees were experts on dredging operations from the WES and experts on various aspects of oyster biology from a number of academic and research institutions along the eastern seaboard.

Meeting format

The meeting format included initial oral presentations from each participant (Table 1). Participants were then divided into two equal-sized subgroups, each having an even representation of experts from all disciplines. Each group was subsequently asked to: (a) determine if a practical numerical model of larval entrainment could be formulated, and if so, to define the components of such a model, (b) determine if such a model could be field-verified, and (c) propose methods by which a dredging operation could be monitored to support decisions on restriction or modification of operations.

Conclusions and recommendations

The workshop resulted in a set of recommendations (Carriker et al. 1986) concerning: (a) the problems associated with sampling and monitoring oyster larval populations, (b) how agencies involved in this or other issues should work together in a spirit of cooperation, as opposed to taking adversarial postures, and (c) proposed simple numerical models of oyster entrainment based on the present level of understanding of oyster larval biology.

Larval dispersion and sampling. The general consensus of workshop participants was that the determination of dredging impacts or the verification of any model through field sampling would be extremely difficult. The reasons for this finding were a fundamentally poor understanding of oyster larval distribution and dispersal (both of which change with larval development) and logistic problems with sampling, processing, and identification of larval bivalves. These problems would make any monitoring program costly and risky in terms of its ability to provide conclusive data.

Table 1
List of Oral Presentation Titles and Speakers for a Workshop on Entrainment of Larval Oysters by Hydraulic Dredges

*Verifying the Need for a Dredging Restriction Due to Entrainment of Oyster Larvae by Glenn Earhart, US Army Engineer District, Baltimore
*Dredging Windows Must be Retained to Protect Chesapeake Bay Oyster Fisheries by Nick Carter, Maryland Department of Natural Resources
*Physicochemical Alteration of the Environment Associated with Hydraulic Cutterhead Dredging by John D. Lunz, US Army Engineer Waterways Experiment Station
*Hydraulic Cutterhead Dredge Entrainment Fields by Clark MacNair, US Army Engineer Waterways Experiment Station
*Oyster Beds of Chesapeake Bay, Virginia by Dexter Haven, Virginia Institute of Marine Science
Oyster Beds of Chesapeake Bay, Maryland by George Krantz, Maryland Department of Natural Resources
*Reproductive Biology and Larval Development of Oysters by Victor Kennedy, Horn Point Laboratory
*Oyster Larval Behavior in Estuaries by Melbourne R. Carriker, University of Delaware
Silt: A Major Inhibitor of Oyster Settling by Clyde MacKenzie, Sandy Hook Laboratory, National Marine Fisheries Service
Oyster Larvae Transport and Spatfall Success by Jay Andrews, Virginia Institute of Marine Science
*Factors Limiting Spatfall Success in Chesapeake Bay by George Abbe, Benedict Laboratory
Circulation Within Chesapeake Bay by Donald W. Pritchard, State University of New York
Prototype in Hydraulic Model Studies of Larval Transport in the James River, Virginia by William Hargis, Virginia Institute of Marine Science
**Arctica islandica* Larvae: Active Depth Regulators or Passive Particles by Roger Mann, Virginia Institute of Marine Science
Modeling Larval Dispersal in Cheasapeake Bay by Don Bach, US Army Engineer Waterways Experiment Station
* Manuscript published as peer-reviewed article in workshop proceedings (list of published titles and authors provided in Appendix A).

Cooperative coordination. A non-technical recommendation proposed by the workshop participants addressed the manner in which agencies should approach unresolved environmental issues. A necessary element of any approach is the need for all parties to work together in a cooperative rather than adversarial manner. Political posturing and preconceived views all too often interfere with addressing and understanding the real questions at hand and can only breed antagonism. Flexibility is also important if adequate resolution of any issue is to be possible. Flexibility is required in

light of the fact that annual variability in natural systems, particularly estuaries, can be quite large and, for the most part, unpredictable. More importantly, flexibility extended by any party must not be perceived as setting a precedent, but only as an acknowledgment of variability inherent in the system in time and space.

Variability between sites can be used to rank proposed project sites based on their value as an oyster spawning or settling area. Highly ranked sites would be those for which seasonal restrictions are justifiable; low rankings would be assigned to areas where dredging schedules could be more flexible. In any case, the need for cooperation, flexibility, and communication is very important. Without these, progress toward issue resolution is not possible.

Larval entrainment model. A simple numerical model of oyster larval entrainment (Carriker et al. 1986) was proposed to serve as an easily applied estimator of potential impact to a given oyster population. The model was based on a set of conservative assumptions about dimensions of bodies of water, dredging operation parameters, and oyster larval distribution. Furthermore, the model was based on proportions to avoid the necessity of making assumptions about absolute values of most parameters.

Major assumptions of the model were conservative and included considerations of the productivity and suitability of the oyster bars present in a waterway, the distribution of late-stage larvae over shoal and channel areas, and their susceptibility to entrainment by a dredge. Input parameters of the model included dimensions of the body of water and the channel to be dredged, duration of spawning and dredging, area of productive oyster bars, and density of late-stage larvae present.

Application of the model to hypothetical wide and narrow waterway examples gave estimates of entrainment of 0.005 and 0.3 percent, respectively. These estimates assume a late-stage larval density of 200 larvae per unit area. In the case of the narrow waterway, the results suggest that the dredging operation imposed minimal direct impact on the late-stage larval population. However, in cases where combinations of a restricted body of water and low densities of late-stage larvae could occur, larger percentages of the population could be lost. An alternative model of entrainment proposed by a workshop participant (Carter 1986) predicted that dredge-induced reductions in larval survival could range from 12.6 to 55.4 percent. Carter's model was based on a much larger set of assumptions about all larval stages and the adult populations. Carter also assumed high densities of late-stage larvae in channel areas where they might be exposed to entrainment. The Carriker et al. model considers only late-stage larvae given high rates of natural mortalities already recognized for early-stage larvae and the apparent tendency for late-stage larvae to concentrate in bottom layers under certain tidal or diurnal conditions.

A general conclusion of the workshop was the realization that present understanding of oyster larval biology (reflected in the assumptions of the Carriker et al. model), is limited and in need of further research before more realistic estimates of dredge-induced effects can be made. This research, while capable of improving the environmental impact prediction capabilities, would be costly and difficult.

Issue: The Effects of Dredging on Pacific Coast Anadromous Fishes

In September 1988 WES sponsored a technical workshop to review the state of knowledge concerning the effects of dredging-induced turbidity upon anadromous fishes in the Pacific Northwest (primarily salmonids, striped bass, and smelt) (Washington Sea Grant Program 1990). LaSalle et al. (in preparation) identified a number of dredging-induced water quality alterations as being of concern to anadromous fish stocks. One major issue was the potential blockage of migration routes of both adult and juvenile fishes by dredging operations (particularly with respect to increased levels of turbidity).

Objective

The overall objective of this workshop was to review the available information on the effects of dredging-induced turbidity upon the physiology, behavior, and survival of anadromous fishes in the Pacific Northwest. Major tasks included: assessing the present issues surrounding dredging impacts, re-evaluating strategies for minimal-impact dredging, and recommending approaches for evaluating and quantifying the more significant impacts. The basic question being asked was "Can anadromous fishes detect and behaviorally avoid suspended sediment concentrations that may be harmful to them?" Issues concerning dredging effects attributable to the toxicity of suspended sediments were not considered.

Chairperson and topic selection

Mr. Charles A. Simenstad of the Fisheries Research Institute of the University of Washington was selected by WES scientists to plan and convene the meeting based on his expertise in the area of salmonid biology and ecology. Mr. Simenstad, in conjunction with the Washington Sea Grant Program, also agreed to edit and publish the proceedings as a Sea Grant publication. Based on his oral presentation, each participant was asked to submit a manuscript, which was peer reviewed prior to publication. Topics of workshop presentations included: aspects of the physical and chemical alterations around an operating dredge, background information

on the physiology and behavior of anadromous fishes in estuaries or their specific responses to suspended sediments, as well as available information on entrainment of fishes and the use of dredged material for habitat enhancement (Table 2).

Committee member selection

Technical experts in each of the topic areas were invited to participate and included experts on dredging operations from WES and experts on various aspects of anadromous fish biology from a number of academic and research institutions along the western seaboard from San Francisco Bay to Puget Sound. In addition to participants, interested personnel from appropriate Federal and State management agencies were invited to observe and ask questions during initial general presentations.

Meeting format

The meeting began with oral presentations from each participant (Table 2) during which questions were invited from both participants and observers. A second working group session, including only participants, was held to discuss the biological basis for any temporal and/or spatial restriction on dredging activities. The probability of impact and the circumstances under which an alteration might impact anadromous fish populations were summarized. In order to evaluate the scale of possible impacts, discussions (and conclusions and recommendations) were subdivided into near-field effects, far-field effects, and ecosystem-level effects. The group was also asked to make recommendations on the types of information needed to further address unresolvable issues.

Conclusions and recommendations

Three categories of potential effects were defined as follows: near-field effects, those associated with immediate injury from contact with suspended sediment or water masses created during dredging activities; far-field effects, those that cause modifications in fish behavior (e.g., migration rate, feeding, predator avoidance) that might result in reduced fitness of the fish over time; and ecosystem effects, those that affect the estuarine ecosystem's ability to provide basic functions of habitat (e.g., for reproduction, refuge from predation, production of prey resources) (Simenstad 1990).

Near-field effects. A general consensus of the group was that the principal mechanisms of potential near-field injury to fishes were through histopathological effects (e.g., hypertrophy and necrosis) on the fishes' gills when exposed to high levels of suspended sediment. In particular, phagocytosis (intercellular incorporation) appears to be the most recognized

Table 2
List of Oral Presentation Titles and Speakers for a Workshop on the Effects of Dredging on Anadromous Fishes on the Pacific Coast

Contemporary Issues Involving Impacts of Dredging Activities by Doug Clarke, US Army Engineer Waterways Experiment Station
*Changes Induced by Dredging by Mark W. LaSalle, US Army Engineer Waterways Experiment Station
*New Revelations on Natural Migratory Behavior of Juvenile Salmon by Thomas P. Quinn, University of Washington
Potential Physiological Impacts on Migratory Behavior by Walter Pearson, Battelle Northwest Marine Research Laboratory
*Effects of Chronic Turbidity on Density and Growth of Steelhead and Coho Salmon by John W. Sigler, Spectrum Sciences and Software
*Suspended Sediment Effects on Striped Bass Eggs/Larvae by Charles Hanson, TENERA Corporation
*Some Sublethal Effects of Suspended Sediments on Juvenile Salmon by James Servizi, Environment Canada
*Turbidity Influences on Feeding Behavior and Implications to Predation Pressure by Robert Gregory, University of British Columbia
*Effects on Columbia River Estuarine Fish of Increased Turbidity Resulting from the Mount St. Helens Eruption by Robert Emmett, National Marine Fisheries Service
*Turbidity and Suspended Sediments at the Alcatraz Dump Site by Douglas Segar, San Francisco State University
*Inwater Disposal of Dredged Materials in Freshwater: Potential for Enhancement? by David Bennett, University of Idaho
*Is Entrainment of Fishes a Significant Impact of Dredging? by David Armstrong, University of Washington
*Entrainment of Fishes at the Mouth of the Columbia River by Kim W. Larson, US Army Engineer District, Portland
* Manuscript published as peer-reviewed article in workshop proceedings (list of published titles and authors provided in Appendix A).

evidence of effects of elevated suspended materials. It appears, however, that phagocytosis is a common phenomenon of juvenile salmon migrating in naturally turbid estuaries and that these organisms have probably adapted physiologically to sediment particle impingement on gill tissues. The coughing response of juvenile salmonids may also be a protective response, rather than a symptom of injury, and evidence suggests that repair of gill tissue begins immediately after cessation of the irritant. A general consensus of the committee was that direct effects on fishes are unlikely to be significant given the established tolerances of most species of concern.

Notable factors determining the potential for impacts from near-field plumes of suspended sediment were thought to be: (a) a fish's ability to detect and avoid elevated levels of suspended sediments, and b) the duration of exposure to elevated levels. In the case of potential blockage of migration due to the presence of a plume, it was the consensus of the group that juveniles would be more vulnerable than adults. While salmonids are known to possess a high capacity to detect and distinguish turbidity and other water quality gradients, it is known that they are not necessarily reluctant to enter highly turbid waters. What is not known is the sensory cue or threshold that will induce fish to alter their natural behavior. Based on available information, entrainment of anadromous fishes did not appear to be a significant source of impact.

Far-field effects. As with near-field effects, the spatial and temporal distribution of elevated levels of suspended sediments and fishes will determine the potential for impact. Although laboratory evidence suggests negative effects of turbidity on feeding behavior and vulnerability to predation, the significance of these responses is less obvious where juvenile fishes are naturally adapted to relatively high turbidity levels. The small spatial scale of most dredging-induced plumes (i.e., plumes encompassing a small proportion of the channel cross section or surface area of a body of water) also make impacts unlikely. On the other hand, if a plume encompasses the majority of the cross section of a channel for a long period of time, it has a greater potential for impact.

Ecosystem effects. It was the consensus of the working group that given the inherently dynamic and non-deterministic nature of estuaries, it was doubtful that ecosystem-level effects could be detected with the current state of knowledge. Excessive sediment accretion from dredging in productive habitats had the greatest potential for impact, but even this scenario was dubious considering the adaptability of most estuarine flora and fauna to rapid rates of sedimentation. Two potential "red flag" situations were, however, identified: (a) dredging within active, cross-current, shallow channels, especially with agitation dredging; and (b) dredging within close proximity to hard substrate communities. Given the continuing controversy about the overall role of dredging in potentially altering fish distributions within estuaries, most of the technical experts within the working group believed that the information needed to detect or assess impacts at this scale does not exist. Factors such as changes in climate, oceanographic effects, as well as historical changes in watersheds and estuaries would confound and obscure the effects of more localized introductions of suspended sediments by dredging or dredged material disposal.

The "bottom line" to the workshop group deliberations was that, "... while there is meager evidence that near-field, direct and ecosystem-level impacts from dredging-associated suspended sediments are significant or common, we do not know enough about fish migrating through estuaries to exclude indirect, far-field effects" (Simenstad 1990). However, presently those far-field efforts have not been identified as problems during dredging projects.

4 Summary and Recommendations

Summary

The use of technical review committees described in this report serves to illustrate the usefulness of this approach toward addressing contentious issues. The approach is based on the premise that all sides of an issue must cooperate in order to reach some meaningful conclusions or understanding of the issue and that conclusions must be based on technically sound information. At a minimum, the process of gathering appropriate technical experts and reviewing available information will lead to establishment of a baseline of information from which conclusions and recommendations can be formed and from which future work can be planned.

Both committees described in this report produced a set of conclusions and recommendations as well as provided an extensive review of available information on various aspects of the issues that were addressed. Not surprisingly, the degree to which any given issue was resolved varied according to the relative amount of available information on the subject. A logical extension, and additional benefit, of this type of effort was the development of a set of recommendations for future types of research efforts and identification of the kinds of data that would be needed to further address an issue.

Recommendations

The process described herein for dealing with unresolved issues appears to be viable in that it can lead to resolution of some issues in a way that is acceptable to the scientific community at large. In fact, the peer-reviewed aspect of the process is the most attractive benefit and fits the desire of the resource management community to return to this practice as a means of avoiding the loss of otherwise valid information within the "gray literature" (Collette 1990; Wilbur 1990). Management agencies could benefit from adapting this philosophy and, in doing so, gain credibility when dealing with controversial issues.

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Appendix A Published Proceedings of Workshops[1]

[1] Table of Contents for Published Proceedings of Workshops on Entrainment of Larval Oysters (*American Malacological Bulletin*, Special Ed. No. 3) and Effects of Dredging on Anadromous Fishes on the Pacific Coast (Washington Sea Grant Program)

Entrainment of Larval Oysters

Effects of Dredging on Anadromous Fishes on the Pacific Coast

Physicochemical Alterations Associated with Dredging
by Mark W. LaSalle, US Army Engineer Waterways Experiment Station

Migratory Behavior of Pacific Salmon in Estuaries: Recent Results with Ultrasonic Telemetry
by Thomas P. Quinn, University of Washington

Effects of Chronic Turbidity on Anadromous Salmonids: Recent Studies and Assessment Techniques Perspective
by John W. Sigler, Spectrum Sciences and Software

Potential Effects of Dredging Activity on Early Life Stages of Striped Bass (Morone saxatilis) in the San Francisco Bay Area
by Charles H. Hanson, TENERA Corp. and Craig P. Walton, Pacific Gas and Electric

Sublethal Effects of Dredged Sediments on Juvenile Salmon
by James Servizi, Environment Canada

Effects of Turbidity on Benthic Foraging and Predation Risk in Juvenile Chinook Salmon
by Robert S. Gregory, University of British Columbia

Effects of the 1980 Mt. St. Helens Eruption on Columbia River Estuarine Fishes: Implications for Dredging in Northwest Estuaries
by Robert L. Emmett, George T. McCabe, Jr., and William D. Muir, National Marine Fisheries Service

Turbidity and Suspended Sediments at the Alcatraz, California, Dumpsite
by Douglas Segar, San Francisco State University

Entrainment of Anadromous Fish by Hopper Dredge at the Mouth of the Columbia River
by Kim W. Larson and Christine E. Mohl, US Army Engineer District, Portland

Fish Entrainment by Dredges in Grays Harbor, Washington
by Katherine A. McGraw, US Army Engineer District, Seattle and David A. Armstrong, University of Washington

Use of Dredged Material to Enhance Fish Habitat in Lower Granite Reservoir, Idaho-Washington
by David H. Bennett, James A. Chandler, Larry K. Dunsmoor, University of Idaho, and Teri Barila, US Army Engineer District, Walla Walla

Summary and Conclusions from Workshop and Working Group Discussions
by Charles A. Simenstad, University of Washington